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GeGI: Chicago field test report (trip #2)

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July 9, 2014

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This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Performance of the GeGI Imager during the 2014 Chicago measurement campaign



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July 7, 2014

LLNL-TR-656851

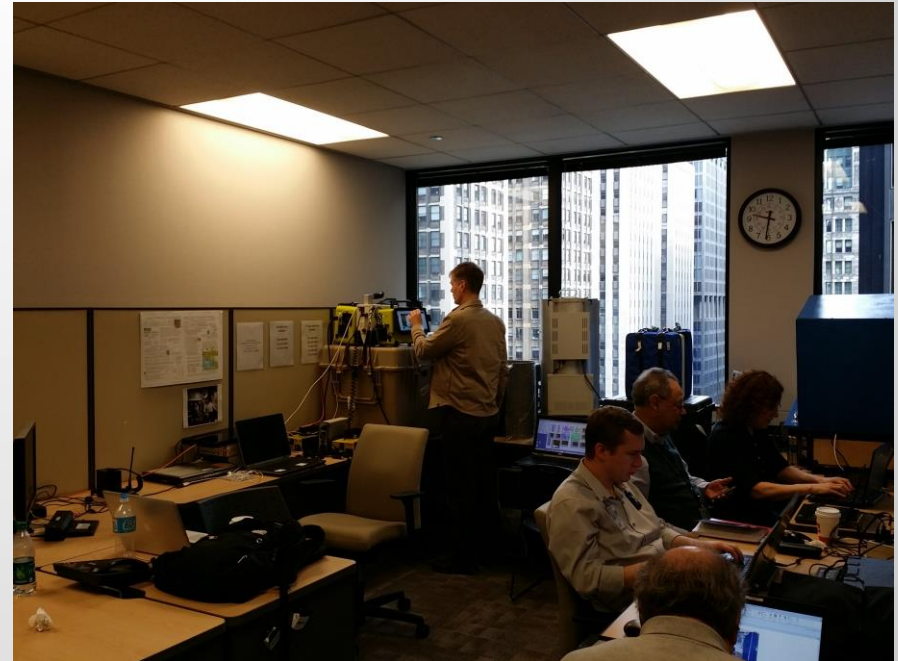
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Chicago Measurement Campaign

- A measurement campaign was carried out in downtown Chicago
- Several labs participated with spectroscopy and imaging for both gamma-rays and neutrons
- The measurement room was on the 12 floor of the Metcalfe building.
- Various types of sources were “hidden” in various floors of an adjacent building.
- *This report describes the performance of the GeGI gamma-ray spectrometer and imaging algorithms developed by LLNL*



Operational Performance

GeGI performed well operationally

1. Transport

One system was transported in a pelican case as carry on luggage

A second system was sent by Fed Ex from PHDS Co.

2. Cool down

Each system required ~5 hours to cool

Systems cooled in hotel the night before

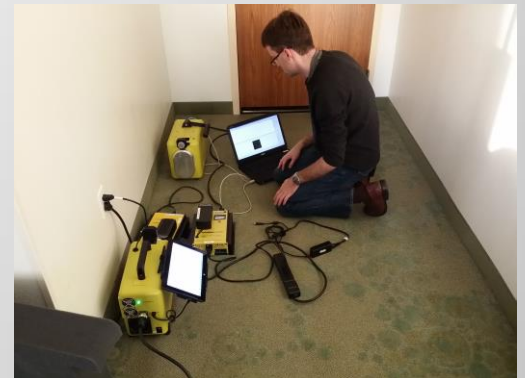
Systems were ready to operate almost immediately in the morning

3. Continuous operation

GeGI ran continuously for several days

long duration measurements

overnight background measurements



Unpacking the two systems and
Beginning cryogenic cooling

Imaging Cs-137 (662 keV)

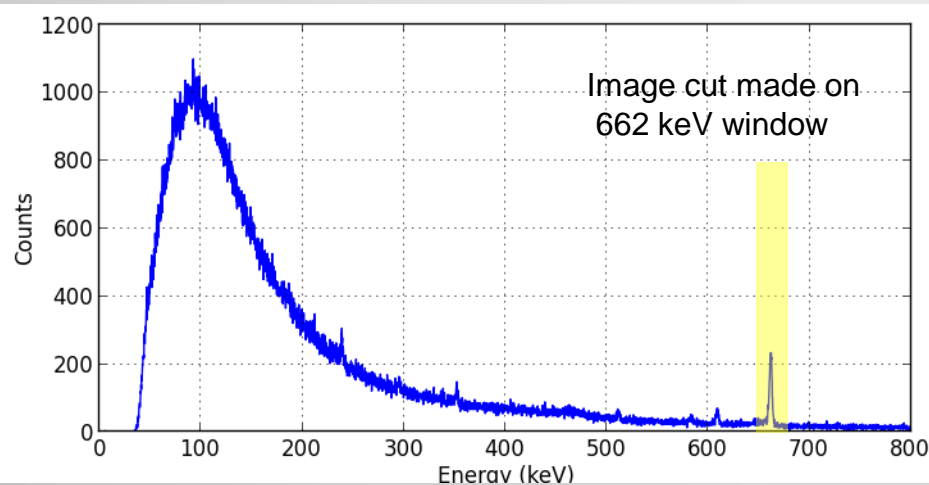


Source: Cs-137

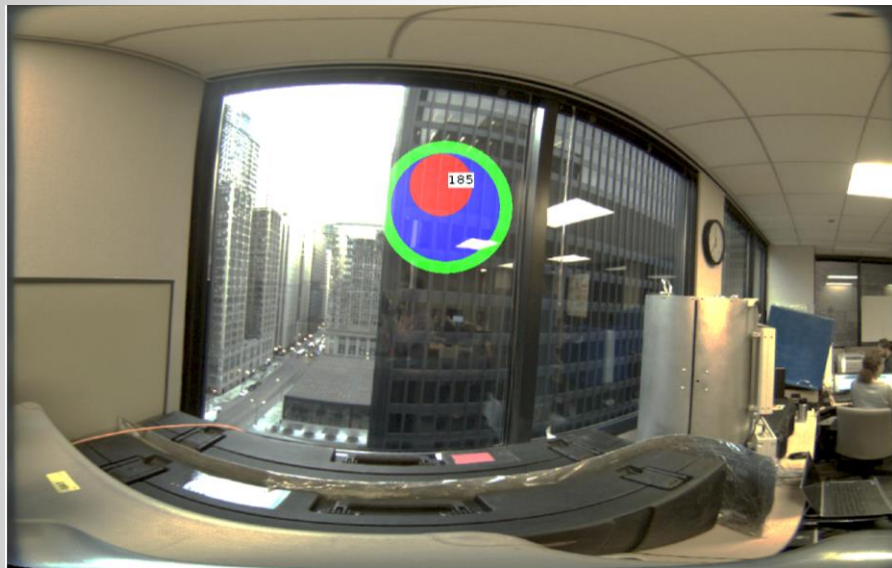
Distance: 25 m

Spectral detection: 1min (8σ)

Image detection: 14min (3σ)



Imaging HEU (186 keV)

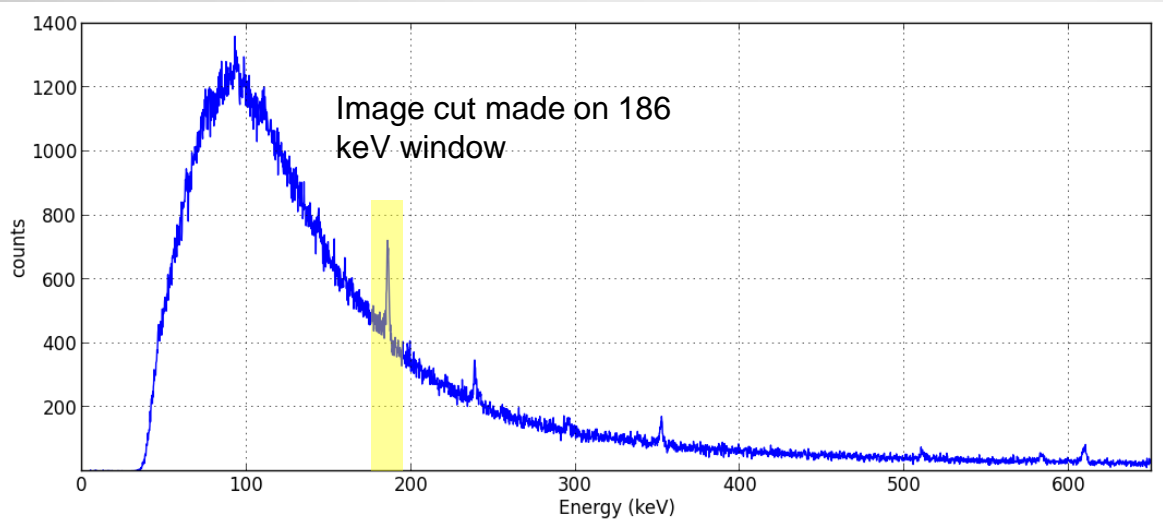


Source: 97 grams HEU (98% enriched)

Distance: 28 m

Spectral detection: 15 min (8σ)

Image detection: 39 min (3σ)



Imaging Ba-133



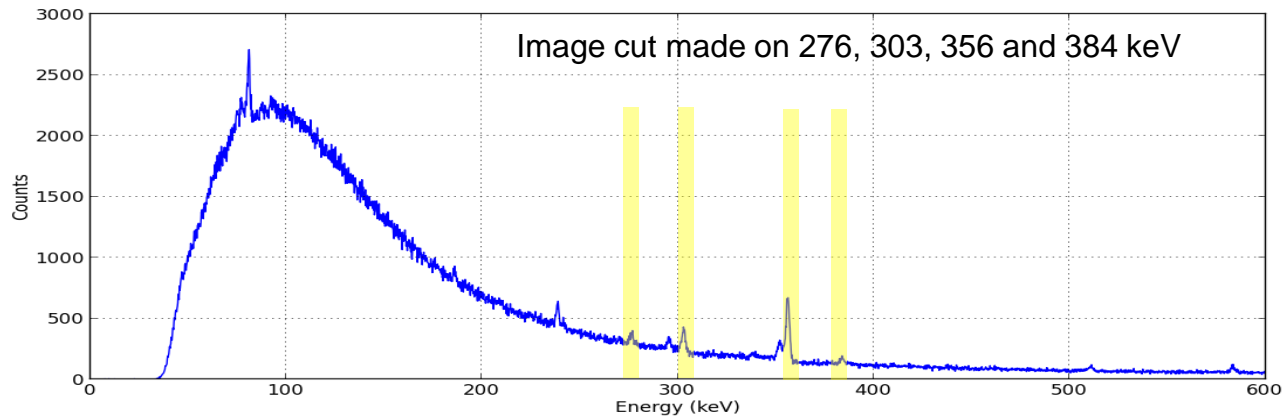
Source: Ba-133

Distance: 28 m

Spectral detection: 3 min (8σ)

Image detection: 11.7 min (3σ)

Note: Ra-226 has line (351.9 keV) that is close to the Ba-133 line (356.02 keV)



Automated Alarming Algorithms

- We developed and tested automated alarming algorithms for GeGI
- These algorithms alarm when
 - a discrete gamma-ray source is detected in spectroscopy
 - or a source is localized in an image
- Automated algorithms serve several purposes
 - Aid the non-expert user by informing them of statistically significant detections
 - Allow unattended monitoring
 - * remotely send an alarm when a source enters or leaves the field of view
 - Give optimal detection sensitivity (since the algorithm can locate a source faster / more accurately than an observer)
 - Quantifying the statistical significance of an image detection
- *For imaging detection, no such method exists. Therefore, we had to develop appropriate algorithms.*

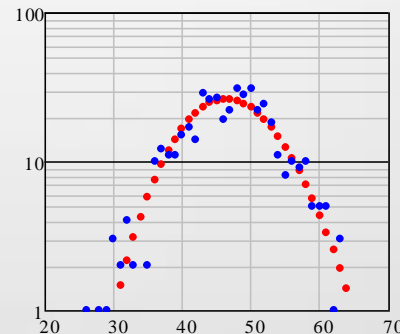
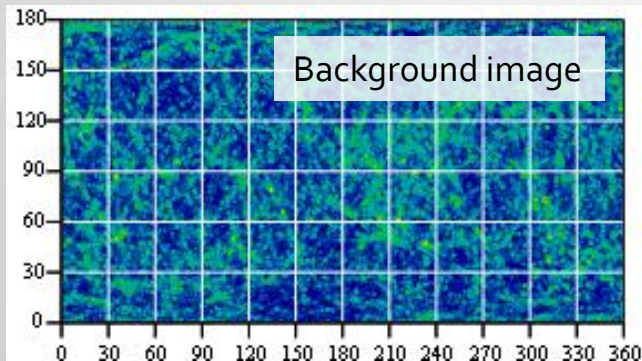
Automated Imaging Detection (Compton Imaging)

- Detecting the statistical significance of a source in a Compton image relies on the observation that random background is Poisson distributed across the image
- A statistically-significant detection relies on observing a deviation from a Poisson background
- Complicating factors include: correlations due to Compton rings; correlations from detector geometry; accounting for variance in stat. significance between pixels; optimizing for finite imaging resolution

Poisson
distribution

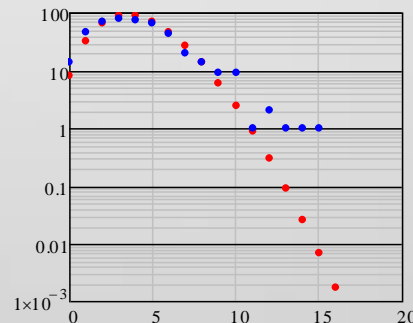
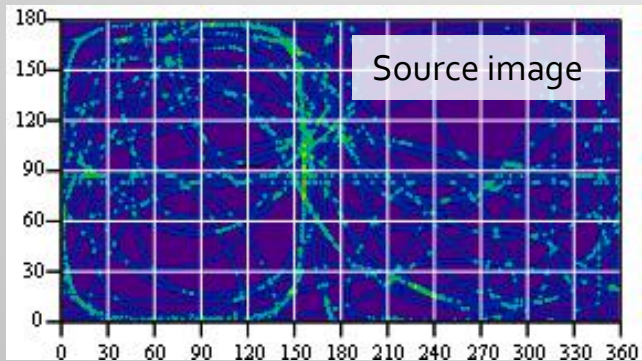
$$P(x) = \frac{\mu^x}{x!} \cdot e^{-\mu}$$

x = intensity of an individual pixel in the image
 μ = mean of all pixels in image



Blue: image histogram
Red: theoretical Poisson distribution

Background image is consistent with random Poisson background



Source image deviates from Poisson.

The amount of deviation is a quantification of statistical significance.

Results: Spectral and Image Alarming

Source	Strength	Distance	Spectral Detection (8 σ)	Image Detection (3 σ)
Cs-137	1 mCi	28 m	1.1 min	19.8 min
Ba-133	0.65 mCi	28 m	3.0 min	11.7 min
HEU	97 grams (98% enriched)	28 m	15 min	39.3 min

- Our automated image detection algorithm showed a significant increase in sensitivity over previous methods
- Spectral imaging used the standard method: signal height compared to background, with a threshold of 8 standard deviations
- A threshold of 3 standard deviations was chosen for the imaging, but this can be adjusted by the user

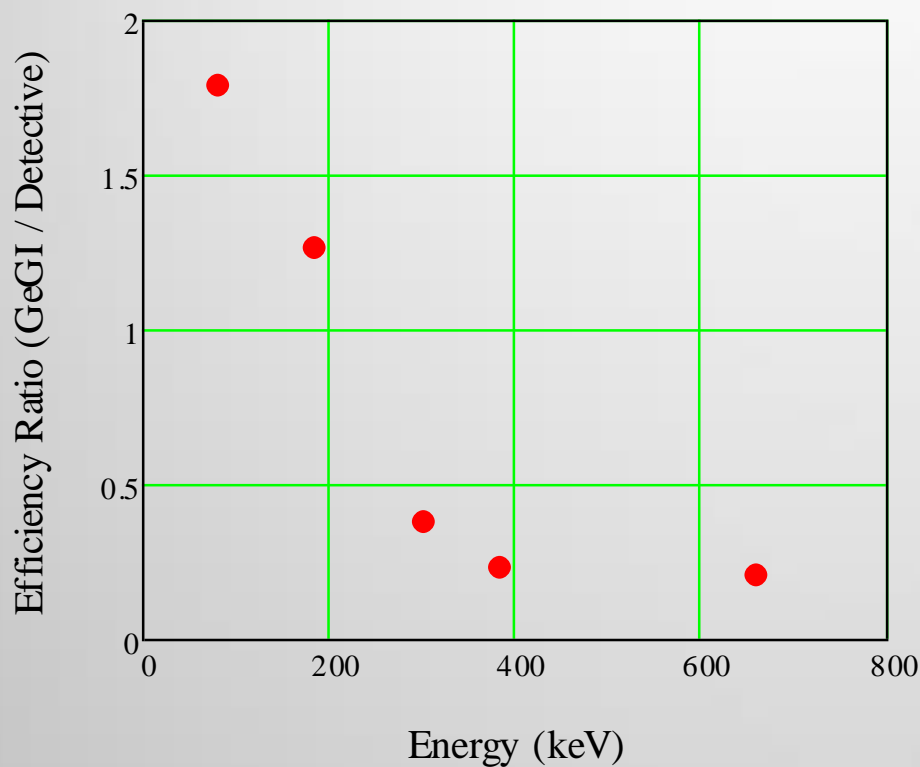
GeGI Detection Sensitivity

Imaging sensitivity: defined at the minimum source strength that can be detected at 10m in one minute. For spectral detection the threshold is 8σ . For imaging the threshold is 3σ .

Source	Spectral Sensitivity (8σ at 10m in one minute)	Imaging Sensitivity (3σ at 10m in one minute)
Cs-137	0.14 mCi	2.5 mCi
Ba-133	0.25 mCi	0.97 mCi
HEU (98%)	186 grams	486 grams

Note that GeGI is able to detect a much smaller quantity of Ba-133 compared to Cs-137. This is due to the fact that Ba-133 has multiple lines to detect.

Relative Efficiency (GeGI vs. Detective Ex)



An Ortec Detective Ex and GeGI were placed side by side for a series of measurements.

GeGI was found to be more efficient at lower energies (including at 186 keV), while the Detective at higher energies.

This explained by the fact that GeGI has larger surface area (so captures more low energy photons) but the Detective is thicker (so better at stopping high energy gamma rays)